Broadband Acoustic Clutter

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LONG TERM GOALS

The long term goal associated with this project is to improve performance of low-mid frequency active sonar systems against clutter

OBJECTIVES

The objectives are to understand the mechanisms that lead to clutter and develop models that predict the temporal/spatial/frequency dependence of the observed clutter.

APPROACH

The experimental approach is based upon exploiting both long-range observations of clutter and short-range, or direct-path observations (both seabed scattering and reflection) of the features that give rise to the clutter. Direct path observations offer two significant advantages: a) the uncertainties associated with propagation (through a generally sparsely sampled ocean) are minimized, and b) the measurement geometries are favorable to producing data from which hypotheses about the scattering mechanisms can be directly tested. The theoretical approach was taken and advanced from energy flux methods (e.g., [1], [2])

WORK COMPLETED

The FY06 efforts included,

1) development of fundamental understanding of the background reverberation against which clutter is observed: we term this "diffuse" reverberation,
2) analysis of broadband clutter from several classes of seabed features
3) development of a measurement strategy for the FY07 experiment in the Straits of Sicily - joint with NRL, DRDC-A, and the NATO Undersea Research Centre, La Spezia Italy (this is ongoing).

Under these main topics, accomplishments included:
a) demonstration of a constrained model-to-reverberation data comparison, where the environmental inputs were measured independently of the reverberation (i.e., no free parameters) b) development of a reverberation model capable of treating scattering from sub-bottom interfaces and comparison of that model with a normal mode approach, c) participation/contribution to the Problem Definition

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Committee for the ONR-PMW-180 Reverberation Workshop, d) analysis of target strength and statistics associated with clutter from an undersea ridge and mud volcano cluster.

RESULTS

A constrained comparison of waveguide reverberation theory and observations: no free parameters
The ability to predict acoustic reverberation in shallow water ocean waveguides is important for the design and employment of active sonar. An important goal has been testing of the theory of reverberation in a waveguide. In order to validate the theory, all of the environmental variables must be obtained independently from the reverberation data (i.e., not obtained by inversion). Such a validation has not yet been made to the author's knowledge, and was one objective of the FY06 work.

The required environmental data (for reverberation dominated by seabed reverberation) includes the sound speed profile, bathymetry and the seabed reflection coefficient and the scattering kernel. The latter two must be measured as functions of angle and frequency. The strategy here was to measure the direct-path seabed scattering strength within a given patch and then measure the reflection coefficient along the source-to-patch-to-receiver path. Measured directional reverberation (using a towed array) at a time and azimuth corresponding to the location of the scattering patch can then be compared with the model predictions using the measured scattering strength and reflection coefficient. In practice, the comparison was made for 9 different observations of reverberation, where the scattering patch is at various ranges (9-13 km) and azimuths (115°-130°), in part to examine possible dependence of scattering strength on azimuth. Fig 1 shows the measured seabed scattering strength at 900 Hz and the seabed reflection coefficient in 1/3 octave bands near 900 Hz. Seabed models fit to the data are also shown (gray lines): an empirical scattering model was used for scattering strength and a layered geoacoustic model for the reflection data (see detailed discussion in [3]).

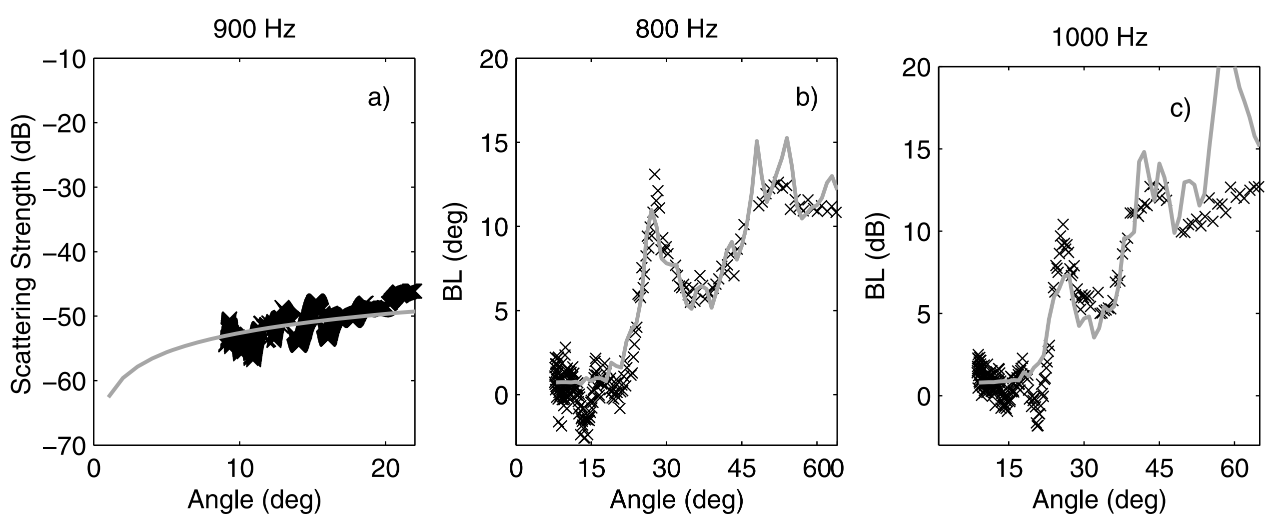

Figure 1. Measured (x) seabed a) scattering strength and b-c) reflection loss on the Malta Plateau. Also shown are the best-fit models (gray lines) to the seabed data (see [3] for details).

The measured reverberation data at 900 Hz are shown in Fig 2 for each of the nine pings. The time associated with the measured scattering patch for each ping is shown in the vertical dashed black line. The large arrival at about 20 seconds in the first few pings is associated with an undersea ridge (the Ragusa Ridge).

Theoretical predictions using an energy flux approach with the measured seabed properties (scattering kernel and reflection coefficient in Fig 1) are shown in red. The red solid line includes noise, which was taken from a 5 second average before the ping (it is useful to see the reverberation both with and without noise in order to ensure that the reverberation-to-noise level is sufficiently high that the comparison is meaningful). The key point to note is that the agreement is good where the beam from the long-range reverberation data intersects with the measured scattering patch (indicated by vertical dotted line). The fact that the model to data agreement is good at other ranges means that the scattering strength and the reflection coefficient are nearly constant over this area (in agreement with [4]). Theoretical predictions were also compared with data at 1800 Hz, and the agreement is very similar to that at 900 Hz (see [3]).

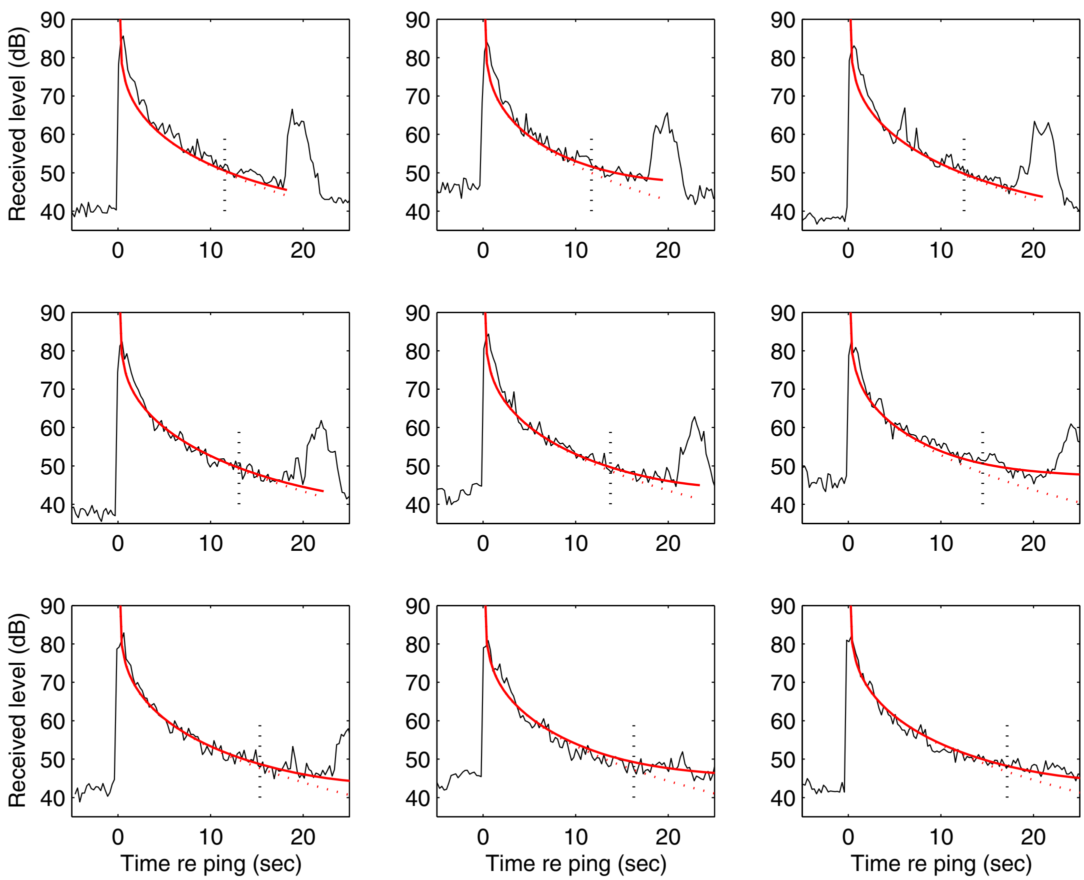

Figure 2. Comparison of measured reverberation (black line) at 900 Hz versus theoretical predictions using measured reflection coefficient and backscatter data (dotted red line). Each panel is a distinct range/azimuth relative to scattering patch.. The location in time corresponding to insonification of the measured scattering site is shown by the vertical black dotted line. The solid red line includes the effect of noise and aids in determining where the data and model are dominated by noise.

This result is important because it is a fundamental step for both the modeling and environmental measurement communities to help demonstrate the validity of the theory and the experimental techniques. It is clearly also a foundational step for addressing clutter.

Long-range observations of clutter from a mud volcano cluster

In FY05, direct path scattering from a 5m high seabed feature in the Straits of Sicily called a mud volcano (MV) was measured and analyzed. The direct path measurements showed that the scattering mechanism was most likely the scattering from the MV itself, as opposed to scattering from emanating gas or particulates in the water column. Target strengths of 4-14 dB were observed from 800- 3600 Hz for a monostatic geometry with grazing angles of 3-5º. Similar target strengths were measured for vertically bi-static paths with incident and scattered grazing angles of 3-5º and 33-50º respectively.

The relative independence on vertical angle of the direct path measurements indicates that target strength is also a useful metric for long-range measurements [5]. One of the FY06 goals was to analyze these data; this analysis is ongoing. Long-range monostatic measurements of clutter were collected in the Straits of Sicily using both incoherent (SUS) and coherent sources, and both a conventional and cardioid towed array. Distance from the source-receiver to the MV (same as analyzed in FY05) along various bearings was about 18 to 20 km. Significant highlights in the reverberation time series corresponding to the location of the MV are apparent in many of the measurements. Sometimes, there is a large single return, more often there are a series of returns as shown in Figure 3 that appear to correspond to the location of other MVs in the same cluster (see Fig 3b).

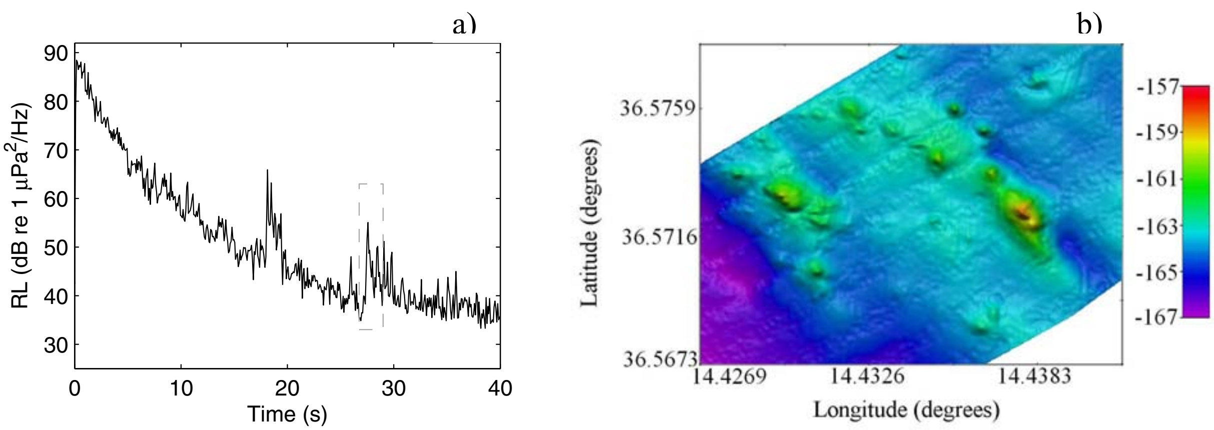

Figure 3. a) Reverberation time series at 1400 Hz, 100 Hz bandwidth that intersects with MV cluster (indicated by dotted gray box). The reverberation from the MV is at 27.5 sec, and is 10-15 dB above the background noise/reverberation. b) multibeam bathymetry of the study area. The protrusions on the seabed are believed to be associated with mud volcanism. The largest MV volcano is the feature probed by direct-path monostatic and vertically bi-static scattering in FY05 and in FY06 by long-range monostatic reverberation. The first arrival in dotted gray box corresponds to this feature.

The measurements are being analyzed for statistics and for target strengths associated with the clutter events. For example, the data in Fig3a associated with the MV show significantly heavier tails than the common Rayleigh assumption (i.e., a higher probability of false alarm for a given threshold). The target strength was estimated by a sonar equation approach, measuring the seabed reflection coefficient and transmission loss along a nearby track and obtaining a geoacoustic model so that propagation from source to seabed at the scatter to receiver could be estimated along the precise track. The resulting target strengths (○) from 5 different shots are shown in Fig 4, the error bars represent the observed variability. Also shown in Fig 4 are the direct path target strengths (♦) and a simple model of target strength from a visco-elastic sphere of radius 5m (gray line). The salient points are that the long-range measurements agree reasonably well with the direct path observations, and the sphere model appears to be a reasonable model (though oversimplified in terms of the physics).

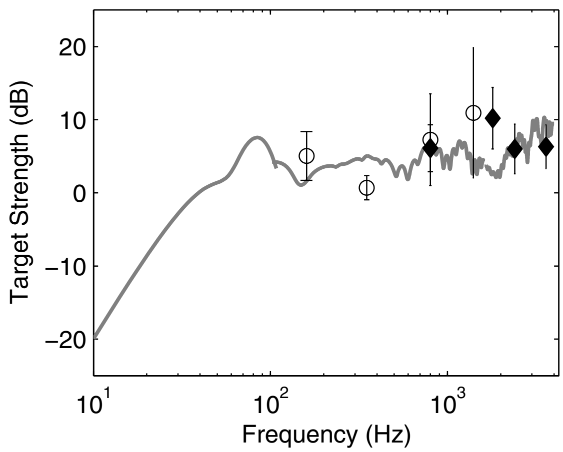

Figure 4. Target strength (○) measured from the largest MV using long-range reverberation at a distance of 20 km for a 100 Hz bandwidth. Also shown are measured target strengths (200 Hz bandwidth) from direct-path measurements [6] from the same MV (♦). Predicted target strength from a sphere of radius 5m is shown in the gray line. Above 100 Hz, the model prediction is averaged over a 100 Hz band and above 1600 Hz, the model is averaged over a 200 Hz band.

IMPACT/APPLICATIONS

The importance of these results are that they 1) provide validation for diffuse reverberation models which forms a crucial foundation for understanding clutter, 2) demonstrate a new experimental approach to measuring/quantifying scattering from seabed features by combined short-range and long-range observations (each with their own strengths and limitations). The statistical characterization of these features will lead to clutter models that can be eventually used in signal processing algorithms to predict and then reduce the impact of clutter. Some of the techniques could have a significant impact on the survey community in terms of tools and strategies.

RELATED PROJECTS

Broadband Clutter Initiative Joint Research Project ONR-NATO SACLANT Centre: this project has goals that are very closely connected with the above project. (2006-2009).

ONR STTR Advanced Physics-Based Modeling of Discrete Clutter and Diffuse Reverberation in the Littoral Environment (2005-2006).

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HONORS/AWARDS/PRIZES

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